Comprehensive Environmental Assessment Report
Sandia National Laboratories
Building 807

1.0 Executive Summary

Over the period of May 14-18, 2001, a comprehensive environmental assessment was performed in Building 807 at Sandia National Laboratories. The objective of the study was to assess environmental conditions in the building that might contribute to a variety of neurological and other symptoms and complaints among workers housed in the northwest quadrant of the first floor. The investigation consisted of:

- Multi-day sampling for volatile organic compounds (VOCs) and formaldehyde on all three floors and in outdoor air;

- Air sampling for other potential neurotoxicants, including organophosphate pesticides and acrylamide;

- Systematic assessment of metals contamination on accessible surfaces and in heating, ventilating, and air-conditioning (HVAC) systems;

- A comprehensive lead-based paint assessment;

- Microbiological sampling for airborne mold;

- Surface sampling for allergens (dust mite and cockroach) and viable mold spores;

- Building-wide assessment of mercury contamination.

1.1 Specific Findings and Conclusions

Specific findings and conclusions of the investigation are as follows:

Volatile Organic Compounds (VOCs)
Overall, indoor VOC levels were very low with respect to occupational exposure standards, and 24 of 25 indoor samples were within the stringent indoor total VOC target guideline of 0.3 mg/m^3. Indoor VOCs were uniformly higher than concurrent outdoor levels, indicating that the building does add VOCs to the background air. While VOC levels in the 1-NW quadrant averaged higher than those in other indoor quadrants, the difference was of only borderline statistical significance when tested at a 5% significance level. In fact, if the one unusually high result is removed from the data set, then statistical elevation of the 1-NW VOC data is rejected at the 12.6% significance level.

Other Airborne Chemicals
Extensive air sampling was conducted in the building for other identified neurotoxicants, including formaldehyde, organophosphate pesticides, and acrylamide. None of these samples found detectable levels of these chemicals.

Carbon Dioxide, Particulate, Temperature and Relative Humidity
Carbon dioxide levels throughout the building were uniformly well below the current American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) guideline, indicating adequate outdoor ventilation rates. It should be noted, however, that the first floor was not occupied during this investigation, and carbon dioxide levels may have been lower as a result. Airborne particulate matter (total dust) was uniformly low. Temperature and relative humidity were well-controlled throughout the course of the investigation.

Airborne Mold Spore Sampling
Two methods were used to measure mold spores at indoor and outdoor locations. One measures total spores (whether viable or non-viable) and speciates them based on their morphology. The other method cultures the collected spores to yield only viable spore counts. It is generally expected that spore count indoors will be lower than those outdoors, unless active growth is occurring or unless previous growth has resulted in release of spores that have not been adequately remediated.

Based on average levels over the week, mold spore counts were higher outdoors than in 1-NW, but the two groups were not statistically different. It is of interest, however, that the spore counts in indoor locations other than 1-NW were significantly lower than those in 1-NW. On two days, the non-viable spore count results in the 1-NW quadrant showed higher counts indoors than outdoors (1,040 vs. 626 and 1,333 vs. 280 spores/m^3), due to elevation in *Penicillium* and/or *Aspergillus* spores. The culturable results did not show this pattern, however. The culturable results also showed different species than the non-viable spore samples.

One possible explanation for these findings is that past flooding and water leaks in 1-NW resulted in mold growth, and spores released in these areas settled to carpeting and possibly other porous surfaces. These spores can be re-suspended through activity, resulting in elevated counts. It is possible that the settled spores had aged to the point that they were no longer viable and therefore did not show up on the culture samples. Based upon visible inspection and lack of discernible mold odors, it did not appear that active mold growth was occurring at the time of this investigation. No highly toxigenic species, such as *Stachybotrys chartarum/atra*, was found in any sample, and toxic species of *Penicillium* (*expansum*) and *Apergillus* (*fumigatus*, *flavus*, and *niger*) were found on only a few samples at very low counts.

Mercury Survey
Of 330 total mercury measurements made throughout the building using a sensitive direct-reading mercury analyzer, three showed non-zero readings, ranging from 0.005 to 0.010 mg/m^3. Two of these non-zero readings were inside or underneath a laboratory fume hood, and the lowest of the three readings was in Room 3006.

Surface and Bulk Dust Metals
A total of 39 surface dust and bulk material samples were analyzed for a panel of 27 metals via ICP analysis. These included bulk dust, wipe samples, and vacuum samples collected from light fixtures, HVAC system components, and various accessible surfaces. Insulation and air filter materials were also collected and analyzed. Thick layers of settled dust were found on the top surface of light fixtures throughout the facility, and these showed varying metal concentrations depending upon the past history of the room or lab sampled. Two samples from laboratory areas showed marked elevation in metals content as compared to samples collected from office areas. Internal surfaces of HVAC systems, air filters, and insulation materials did not appear to have elevated concentrations of metals. The significance of moderate elevations of metals in settled dust to past employee exposures is unknown, and difficult to estimate.

Surface Allergens and Mold
Carpet dust vacuum samples were collected in 10 locations in the building and analyzed for dust mite and cockroach allergens. The dust was also cultured to determine concentration and species of viable mold spores. Dust mite allergens were low to non-detectable in all samples. Cockroach allergens were high in one office location (office J, first floor, NW quadrant), moderate Room 1024 (1-SE) and low to non-detectable in the other eight samples. Viable mold spores in dust ranged from moderate to extremely high (11,000 to >2,500,000 spores per gram of dust). It could not be determined whether the high mold concentration was due to past flooding and growth of mold or to some other mode of contamination by fungal spores. The mold species identified in the samples occur commonly in outdoor and indoor environments, and are not known to be especially toxigenic.

Lead Survey
The lead and lead-based paint (LBP) survey consisted of 873 measurements with a direct-reading X-Ray Fluorescence LBP analyzer, 10 paint chip samples analyzed by Atomic Absorption Spectroscopy (AAS), and 24 surface wipes analyzed via AAS. Except for a few exterior and mechanical room equipment surfaces, Building 807 is largely devoid of lead paint. Only one surface was found throughout labs and offices in the building that contained lead paint—this was a green metal cabinet in Room 2100. The majority of LBP surfaces were found in basement mechanical areas or on exterior railings and posts. Paint surfaces were generally in good condition throughout the facility. It thus appears unlikely that lead dust is being added to the building environment as a result of LBP. Wipe sampling for lead on hard surfaces showed an elevated lead loading on a ceiling light fixture (consistent with the findings of bulk sampling for metals) and one elevated level on a floor in a former lab space that worked with lead-containing materials. Overall, it does not appear that LBP is a serious issue in Building 807, or that it could have contributed significantly to lead exposures in the building, past or present.

HVAC Systems
The main East and West air handlers appeared to be well-designed, operated, and maintained, but the Induction system filter bank, as found at the time of this investigation, was substandard. The lack of efficient outside air dust filtration may have been the cause of particulate complaints in the building. There are plans to renovate the filter bank, and this should reduce the dust and soiling problems noted in perimeter offices.

1.2 Overall Assessment of Current Building Conditions

Based upon the findings of this investigation, Building 807 is felt to be safe for occupancy. No concerns were found on the second and third floors, although settled dust samples in three current or former laboratories showed some elevation of metals compared to those in office locations. The metal levels found in the laboratories are not judged to be sufficiently high to pose a hazard to occupants or to employees who might later be engaged in cleaning operations.

There was some evidence of past mold growth on carpeting, based upon dust collection and laboratory culturing of this dust. Airborne levels of viable mold spores were uniformly low. Airborne levels of total spores measured through non-viable methodology showed generally acceptable levels, although two samples taken in the 1-NW quadrant exceeded the concurrent outdoor levels. (The two indoor samples showed 1,040 and 1,333 spores/m^3 while the outdoor samples measured 626 and 280 spores/m^3.) The general impression is that past water leaks have resulted in growth of mold at some locations on carpets, and that spore levels in dust remain high, since no cleaning or vacuuming has occurred in this area for several months. Steps should be taken to thoroughly clean carpeted areas known or suspected to have had water or moisture problems prior to re-occupancy. Once this is completed, renovation can proceed on the first floor without special precautions, with the possible exception of areas that are known by Sandia to have asbestos-containing materials.

The filtration system on the outside air inlet to the building perimeter HVAC system (the "Induction" system) is substandard and should be upgraded as soon as possible. The question was raised as to whether this poor filtration efficiency has resulted in accumulation of dust and debris in the Induction system ductwork. Visual inspection was performed on accessible portions of the Induction system (at the fan unit, return air filtration bank, and main supply risers) and a video system was used in an attempt to image inaccessible portions. The visual inspection did not indicate unusual soiling or accumulations. Attempts to use video imaging equipment to in the Induction system ductwork were only partially successful due to sharp bends and small ducting. Only the main horizontal duct past the vertical riser from the fan unit and a few feet of terminal ductwork at two locations in 1-NW could be viewed. While these sections of ductwork also appeared to be reasonably clean, only a very small portion of the system was viewed.

It appears that the flow velocities in the Induction system ductwork are sufficient to transport particulate out through the wall units. The soiling of the filter material added to the wall units supports this view. However, additional attempts should be made to image internal portions of this system to determine whether duct cleaning is warranted.

1.3 Historical Exposure Assessment

While the scope of this investigation was to perform a comprehensive assessment of *current* conditions in the building, there is considerable interest in making estimates of past exposures that may have occurred in the building. It well understood that it is difficult to use current information to draw conclusions about past exposures, and the level of effort required to do this with confidence is large. While such an effort was not within the scope of this study, the on-going epidemiological study may provide additional insight into past conditions. These caveats notwithstanding, in attempting to *speculate* about past exposures, it is necessary to consider several important facts about the building and the operations that occurred there, as follows:

- The East and West end HVAC systems serving Building 807 have undergone some change (conversion from dual duct to single duct VAV), but the fan units and main ducting have not been altered much. The Induction system has changed only in terms of the outside air filtration system, which, if anything, is probably less efficient at present than in the past.

- There have not been major renovations over the history of the building. Internal walls have been removed and changed in some areas, but many areas of the building have reportedly undergone very little change.

- Occupancies and operations performed in labs and work spaces have varied over the years, but there is no accurate data on variations in use of chemicals, metals, and other hazardous agents. It does not appear, however, that operations in the past used vastly larger amounts of hazardous materials than in more recent years.

- Accumulations of dust were found throughout the building that might be representative of past operations, but the "age" of this dust is a matter of speculation. These samples provide some insight with respect to past levels or emissions of metals, but provide no information about past use of volatile chemicals. By their very nature, measurable traces of volatile chemicals do not remain for long in buildings.

- Building 807 contains very little wood or wallboard, the internal walls in floors 1 through 3 are essentially all metal with rock wool insulation, and most of the carpeting is adhesive-backed synthetic over concrete substrate. As such, the building is considerably less prone to mold infestation than buildings that have substantial wood and wallboard components.

- A good industrial hygiene program has existed at Sandia for many years. Studies specific to Building 807 date back to the early 1980's, becoming more numerous through the 1990's. Building inspections and surveillance of hazardous conditions and exposures have occurred frequently over the last twenty years.

- Essentially all of the potential neurotoxicants identified and investigated in this study have occupational exposure standards, including Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs) and/or American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs). These standards are aimed at preventing long-term exposures that could result in toxic effects, including neurotoxicity, and the standard include an adequate margin of safety.

- Based upon our understanding of past chemical operations and exposure monitoring conducted by Sandia, it appears unlikely that exposures in laboratory operations would have approached occupational exposure limits on any consistent basis. Exposure to chemicals and metals among office workers in the building would have been much lower.

- A review of current literature found one article that tied neurological effects to a very high exposure to toxic strains of *Aspergillus* mold, but these effects were reversible. No literature was found indicating that mold spore exposures in commercial or residential buildings has resulted in irreversible neuropathy.

These facts and observations, coupled with the findings of the environmental assessment, lead us to the conclusion that it is very unlikely that chemical or biological exposures within the building would have risen to levels that would result in irreversible neurotoxic or other systemic toxic effects. However, we cannot rule out the possibility that transient low level mold or chemical exposures may have existed in the past that could lead to the types of non-specific employee symptoms and complaints typically encountered in "sick building syndrome" cases.

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2.0 Introduction and Background

In response to a variety of neurological (and possibly other) symptoms and complaints among workers on the first floor of Building 807, Sandia National Laboratories contracted IHI Environmental to perform a multi-phased project aimed at assessing environmental conditions within the building that might contribute to these symptoms. There has been concern among some current and former Building 807 occupants that there may be an unusual cluster of neurologic and other symptoms, centering on the first floor northwest portion of the building, and dating back at least a decade. A concurrent epidemiological study, performed by researchers at the University of New Mexico, is underway on the Building 807 cohort, but results of this study will not be available for some time.

Responses to the problems at Building 807 have been overseen by a Management Action Team and an employee based Health Advisory Committee. IHI worked closely with these Sandia personnel to assure that the study objectives and design were congruent with Sandia's needs. The history of complaints and symptoms and internal responses by Sandia's medical and industrial hygiene departments has been well documented, and the complete history has not been repeated in this report.

The first phase of the project was to perform a literature review to identify chemical and biological agents that have been associated with neurotoxic effects and with peripheral neuropathy in particular. The results of that review were the subject of a previous report and presentation to the Health Advisory Committee. A summary of the findings is included in Section 2.1 of this report. The information developed in Phase I was used to develop a detailed plan for the second phase of the project, a comprehensive environmental assessment of the building. The scope and design of the environmental assessment are discussed in Section 2.2.

The environmental assessment project was managed by Kenneth L. White, MSPH, CIH. On-site air and environmental monitoring was performed over the period of May 14-18, 2001 by Mr. White, Mr. Amir Karamati, MSPH, and Ms. Shiela Fisher, Industrial Hygienist. The project team was assisted by Mr. Johnny Vaughan, ES&H Coordinator.

2.1 Phase I

The Phase I scope of work was outlined in Sandia's Document 16819, "Building 807 Health Assessment." As originally envisioned, the study was to comprise up to six phases aimed at determining potential building-related environmental conditions and contaminants that may have contributed to a variety of symptoms and health conditions among current and former building occupants. Phase I included two major tasks:

- Perform a literature search to obtain current information on chemical or microbiological agents that might cause neurological and respiratory symptoms, with emphasis on peripheral neuropathy.

- Develop three options (low, medium, and high price alternatives) for conducting a comprehensive industrial hygiene/environmental study of the building. While the scope originally developed by the Committee anticipated two separate studies, one aimed at determining contaminants present in building materials and one aimed at quantifying exposures, it was decided that a single, comprehensive field study would be performed.

In addition, a thorough review has been conducted of previous industrial hygiene and environmental data from Building 807. While not specified in the scope of work, it was felt that this was an important prerequisite to designing the current study. These data include industrial hygiene investigations, water sampling data, and chemical waste disposal data covering much of the 1990's. The Phase I report summarized these internal studies and findings.

2.1.1 Summary of Literature Review

Working in conjunction with information specialists at the University of Utah, Eccles Medical Library, a comprehensive search strategy was developed to yield published articles and texts dealing with neurotoxicity or peripheral neuropathy caused by chemical, environmental, or microbiological contaminants. As discussed with the Health Advisory Committee in our initial project meeting, it was decided that searching for chemicals and agents associated with respiratory symptoms would yield such a large list of chemicals that it would be of little value. The searches were run on the Medline databases, including Toxline, and covered the time range of approximately 1970 to present. Over a thousand articles were found by the searches; bibliographies with abstracts were retrieved for each. These were manually reviewed and the most relevant were retained in a "short-list" of several hundred articles. The list of articles, with abstracts, are available upon request.

It should be noted that in spite of specific searches aimed at identifying microbiological substances associated with neurotoxicity, little was found in this regard. Most of the "hits" in this search dealt with botulinin toxin, natural toxins such as spider and snake venom, and poisonous mushrooms, some of which contain tremorigenic toxins. No articles were found specific to neurologic effects of fungal spores or "molds."

The purpose of the literature search was not to prepare a detailed written review of neurotoxicity, but to identify those chemicals and agents potentially present in the work-place (including laboratories) that are most strongly associated with neurotoxic effects. As the relevant citations were reviewed, a list of neurotoxic chemicals was developed. Table 2.1 provides summary information on the chemicals developed through this process. We then assessed industrial hygiene and chemical information on Building 807 to determine the potential that these neurotoxins might have been present in the building. The environmental assessment plans were then developed to address those chemical neurotoxins that had a reasonable chance of having been present in the building and to which significant exposures may have occurred.

2.1.2 Summary of Building 807 Environmental Data and Studies

Many industrial hygiene studies have been performed by Sandia environmental, safety, and health staff in Building 807 over the last 20 years. Sampling has been performed to quantify a wide array of air and surface contaminants in the building and, in general, these studies have found acceptable levels of contaminants. However, some gaps were found in studies performed prior to development of the current study, as listed below. In addition, the Health Advisory Committee felt that it was important that a comprehensive study be performed by an outside consultant. Study gaps that were addressed in the current study included:

- Multi-day sampling for volatile organic compounds (VOCs) and formaldehyde on all three floors and in outdoor air using a highly sensitive method

- Air sampling for other neurotoxicants, including organophosphate pesticides and acrylamide

- Systematic assessment of metals contamination on accessible surfaces and in heating, ventilating, and air-conditioning (HVAC) systems

- Comprehensive lead-based paint assessment

- Microbiological sampling for airborne mold

- Surface sampling for allergens (dust mite and cockroach) and viable mold spores

- Building-wide assessment of mercury contamination

Historical chemical inventories were not available for Building 807, but a detailed database on chemical wastes disposed of from the building was provided. This database spans the period of approximately 1992 to present, with waste chemicals listed by room number. The database was perused and compared against the neurotoxic compounds listed in Table 2.1. This information, along with information gleaned from the industrial hygiene evaluations, was used to fill in the column titled “Presence in 807” in Table 2.1.

2.2 Phase II Environmental Assessment

The major objective of the Building 807 environmental assessment was to perform measurements that would adequately characterize the existing building environment for a variety of potential exposures that may contribute to the current symptoms and to search for residual substances that may have contributed to symptoms that occurred over the last 10 years.

2.2.1 Development of Three Sampling Plan Cost Options

Sandia's RFP requested that three cost options, low cost, medium cost, and high cost, be developed for the environmental assessment. The Building 807 Committee selected the high cost option (with minor modifications), and this option was used to develop the detailed sampling plan that was carried out in the building.

2.2.2 Detailed Sampling Plan

For purposes of the study and statistical analysis of the collected data, Building 807 was divided into four quadrants, down the mid lines of the long and short axes of the building, or northwest, northeast, southwest, and southeast quadrants. This division conforms with the HVAC systems serving the building. The main air handlers are located at opposite ends (east and west) of the long axis of the building, dividing the building into east and west halves with respect to the main or core air flow. A perimeter HVAC system provides heating, air-conditioning and ventilation along exterior walls. This air is provided by a single air handler, but the flow splits into separate ducting systems that serve the north and south sides of the building. Thus, based upon the configuration of the HVAC systems, stratifying sampling within the four quadrants on each floor makes sense. Further, the identified problem area is located entirely within the first floor northwest (1-NW) quadrant. Table 2.2 presents a summary of the sampling that was performed, including numbers of samples taken in the 1-NW quadrant, at other indoor locations, in outside air, and number of field blanks.

2.2.3 Statistical Considerations

The sampling plan was designed to test the following hypotheses:

1. Null hypothesis 1: Levels of contaminants (chemicals, metals, microbiological, etc., in air or on surfaces) in the Building 807 "problem area" (quadrant 1-NW) are statistically equivalent, at the 95% confidence interval, to those present in other areas of Building 807.

2. Null hypothesis 2: Levels of contaminants measured in Building 807 are not elevated (at 95% confidence interval) above consensus standards or guidelines for such contaminants in office buildings, or where consensus standards/guidelines do not exist, above "expected levels" based upon published studies or prior experience.

    2a. If null hypothesis 1 proves true: (i.e., contaminants in the problem area are not statistically different than those present in other building areas) the combined contaminant levels for all areas of Building 807 will be compared statistically to standards, guidelines, or expected levels.

2b. If null hypothesis 1 proves false: (i.e., problem area contaminant levels are not equivalent to non-problem areas) both data sets will be compared statistically against standards, guidelines, or expected levels.

3. Null hypothesis 3: Levels of volatile organic compounds (VOCs), formaldehyde, and bioaerosols in Building 807 are statistically equivalent (95% confidence interval) to concurrent outdoor or "background" levels. (Note: outdoor samples were not taken for organophosphate pesticides or amines, nor was wipe sampling performed out of doors.)

2.3 Building Description

2.3.1 General

Building 807 is a three story, with partial basement, rectangular-shaped building of concrete and brick construction. Figure 2.1 presents schematics of each floor. Floors 1 through 3 each contain about 20,000 square feet of gross space, with 10,000 square feet in the basement, for a total of about 70,000 square feet. Construction was completed in 1966. Building 807 is part of a 3-building complex (805, 806, and 807); it connects via two walkways to building 806, but each building has separate mechanical systems. Throughout its history, Building 807 has housed offices and "light" laboratories (electrical, chemical, and radiological) for a variety of Sandia organizations.

At the time of this environmental assessment, the first floor was empty of occupants and much of the contents and furniture had been removed. The Aerospace Systems Development group (15400) had relocated to another building at Sandia a month or so prior to the investigation. No cleaning had occurred on the first floor in the interim between moving out and the investigation. The second and third floors were still occupied, and operations there were normal.

2.3.2 Description HVAC Systems

Building 807 is served by three separate HVAC systems, all located in the basement/mechanical area. These are the East and West Air handlers, and the Induction System. Figure 2.1, Basement/Mechanical shows the locations of the three systems.

The East and West units are essentially identical, with the east system supplying air to the eastern half of floors 1-3, and the West unit supplying the western half. The air handlers have 75 horsepower, 60,000 cubic feet per minute (CFM) fans. These systems provide tempered, filtered air through ceiling diffusers on all three floors; return air travels through an open plenum above the drop-tile ceiling to return ducts. There are no return air or relief fans. These systems were originally designed and built as dual duct systems—that is, hot and cold air were provided through separate ducts and were mixed to provide desired temperatures at mixing boxes above the ceiling. Each mixing box served multiple ceiling-mounted diffusers. At some point in time, the dual duct approach was abandoned and the hot duct was converted to a cold duct. Variable air volume (VAV) boxes were installed to provide temperature control. VAV systems provide only cool air, and the air flow rate is modulated to produce desired temperatures.

The East and West units draw outside air through filter banks located below grade on the south side of the building. The filters in use at the time of this investigation were 20 X 20 X 2-inch pleated (Flanders Precision Aire Pre-Pleat). The filters in the East and West end units appeared to fit well and were reasonably clean. Variable dampers vary the proportion of outside air versus return air drawn into the system. When outside temperatures are moderate, more outside air is provided; when temperatures are very cold or hot, the outside air dampers close down, allowing no more than about 5-10% outside air. While there are no return air or "relief" fans associated with the main HVAC systems, there are several laboratory fume hoods located on the second and third floor of the building and there are exhaust fans in each rest room. When operating fully, these would help to eject large amounts of air and may prevent the building from becoming "over-pressured" when large amounts of outside air are being provided to the building.

The third air handling system is referred to as the Induction System. This system is centrally located in the basement and has a 25 horsepower, 17,000 CFM fan. It provides conditioned air to the perimeter of the building through units mounted on exterior walls, beneath the windows. Offices typically have two units, while larger spaces may have more than two. Air is emitted from the wall units through upward pointing "jets" and this flow "induces" room air to travel into louvers at the base of the unit, up through the coils, mixing with the air supplied by the jets, and then out through supply louvers on the top of the units. These units are located on all three floors. The main supply air splits into two halves to serve both the north and south sides of the building. The ducting is located beneath each floor, with risers each serving about four wall units. Hot water heating coils are located in each unit to allow additional heating of perimeter spaces in cold weather.

These Induction units have reportedly emitted "black dust" that has been the source of complaints in many of the perimeter offices. A coarse filter material, presumably polyethylene, had been placed under the supply gratings on many of the Induction units, particularly on the first floor. This filter material was noted to have collected considerable dark particulate in many locations. Samples of this material were taken and analyzed for metals in this investigation, and previous sampling and analysis had been performed on this material by the Sandia industrial hygiene staff. It is entirely possible that the poor design and maintenance of the Induction system outside air filter bank is responsible for this particulate matter. Outside air is drawn in at the basement level on the south side of the building. At the time of this investigation, one or more filters were missing and it appeared that the filters did not fit tightly even when in place. As a result, the filtration efficiency is low on this system. The Induction system does have an additional filter bank for return air. These filters would help remove dust in return air but would have no effect on outside air in its first pass through the building. It should be noted that the east and west air handler filter banks appeared to be of much better design; filters were in place and fit much better.

The location of the outside air intakes for all three air handlers in below-grade wells makes them susceptible to entrainment of vehicular exhaust from the parking and loading dock areas south of Building 807. There have been many documented complaints of exhaust smells in the building. This was addressed by using barriers to keep vehicles farther away from the inlets and by prohibiting trucks from idling while unloading. The inlets are well located with respect to laboratory fume hood exhaust points on the roof, and it is unlikely that much if any re-entrainment of lab hood exhaust would occur. There has also been some concern about effluents from the cooling tower located on the roof directly above the Induction unit intakes. Under some wind conditions, cooling tower emissions fall directly down into the well area where the Induction system intakes are located.

3.0 Description of Methods and Equipment

3.1 Volatile Organic Compounds (VOCs)

VOCs will be measured through a highly sensitive, broad spectrum method which is capable of quantifying a high percentage of the chemical air contaminants associated with indoor air quality problems. The method makes use of Carbotrap 300 adsorption tubes and battery operated pumps. The air sampling rate is nominally 0.1 liters per minute (LPM) and sample volume may be from twenty to thirty liters. The Carbotrap tubes will be submitted to DataChem Laboratory for analysis by thermal desorption and gas chromatography, mass spectroscopy (GC/MS). DataChem is accredited by the American Industrial Hygiene Association (AIHA) for analysis of industrial hygiene samples. The analysis quantifies 56 "target analytes" along with the ten most significant non-target peaks. These latter peaks are identified tentatively using the NIST spectral library.

3.2 Formaldehyde

Airborne formaldehyde were collected on Orbo 23 adsorbent tubes at a nominal flow rate of 0.2 LPM using battery operated pumps. Air flows were set and checked using a precision rotameter which had been calibrated on site against a Gilibrator Primary Flow Calibrator. The collected tubes were analyzed following NIOSH Method 2541. The limit of detection of the analytical method is reported as 0.3 µg formaldehyde per sample, which provides sensitivity down to about 10 ppb.

3.3 Carbon Dioxide, Temperature, Relative Humidity

Carbon dioxide, temperature, and relative humidity will be measured using a TSI Model 8550 Q-Trak IAQ Monitor. The unit is calibrated prior to use with certified zero gas and 1,000 ppm CO_2 span gasses. The CO_2 measurements are taken in the morning and afternoon throughout each building in order to determine adequacy of outside air flow. The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) in their Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, requires that 20 CFM of outside air be supplied per occupant in office areas. When this standard is met, CO_2 concentrations should not exceed 1,000 ppm. Outside air contains about 350 ppm of CO_2, and elevations in CO_2 levels in indoor spaces results from occupants' exhaled breath. Monitoring of CO_2 levels thus serves as a convenient way to determine whether outside air flows are adequate and effectively distributed in all portions of a building.

3.4 Total Dust

Airborne particulate matter (dust) was monitored using a Casella MicroDust Pro Aerosol Monitoring System. This is a direct-reading instrument that makes use of the principle of forward scattering of infrared light by particles in air. The instrument can measure dust concentrations ranging from 0.001 to 2,500 mg/m^3. The instrument was used to obtain spot readings of dust concentrations at multiple locations in the building.

3.5 Organophosphorous Pesticide Scan

Area air samples were obtained within the building following NIOSH Method 5600. Air samples are collected using OVS-2 sorbent tubes (XAD-2, 270/140 mg) at a flow rate of approximately 1.0 LPM. Air flows were set and checked using a precision rotameter which had been calibrated on site against a Gilibrator Primary Flow Calibrator. The samples were submitted to DataChem Laboratory of Salt Lake City for analysis of the organophosphorous pesticides via GC/FPD analysis.

3.6 Acrylamide

Air samples for acrylamide were collected on silica gel tubes at a nominal flow rate of 0.1 LPM using battery operated pumps. Air flows were set and checked using a precision rotameter which had been calibrated on site against a Gilibrator Primary Flow Calibrator. Samples were analyzed by DataChem laboratory via OSHA Method 21, which uses gas chromatography with a nitrogen phosphorous detector.

3.7 Microbiological Sampling

Air samples for total spores and pollens were collected on Zefon Air-O-Cell air sampling cassettes; these samplers impact particulate on a glass slide substrate for direct microscopic analysis. Sample air flow rates are set at 15LPM with a sampling duration of 3 minutes; flows are measured with a precision rotameter, previously calibrated using a Gilian Gilibrator® Primary Flow Calibrator. Results are reported as spores per cubic meter of air. Concurrent outside air samples are always taken to allow comparison of indoor spore levels to those occurring out of doors at the time of sampling.

Speciation of some fungal types (especially aspergillus and penicillium) requires collection on agar plates and culturing. An Anderson N-6 impactor fitted with malt agar culture media was used to collect these samples. The required flow rate for the N-6 impactor is 28.3 LPM and sampling duration was 3 minutes to provide an air volume of 84.9 liters. Analyses of microbiological samples were performed by Environmental Microbiology Laboratory of Escondido, California. Their analytical reports are included in Volume II, Tab B.

3.8 Mercury

Elemental mercury vapor was measured throughout the building using a Jerome 431-X Mercury Vapor Analyzer provided by Sandia. The serial number for this instrument was 1995, with sensor number 99-11-17rld. It was calibrated by Arizona Instrument on November 30, 2000, with standard units traceable to NIST. This is a highly sensitive (to 0.001 mg/m^3), direct-reading instrument that uses a highly specific gold-foil technology. Measurements were made at "breathing zone" height within each room. The instrument was also be used to sample near the floor, in cracks and corners where mercury contamination can remain for long periods. All accessible laboratory spaces were surveyed along with approximately 50% of non-laboratory rooms, randomly selected.

3.9 Surface/Bulk Metals

Surface and bulk materials samples were obtained for metals analysis via Inductively Coupled Plasma (ICP) analysis. Wipe samples were collected using Ghost Wipes™ manufactured by Environmental Express; these wipes meet the requirements of ASTM E1792-96a, "Standard Specification for Wipe Sampling Materials for Lead in Surface Dust." Clean plastic templates were used to wipe areas of known size; the area was wiped in a horizontal pattern, followed by a second wiping in a vertical pattern. A second wipe was used where surface loadings were heavy. Wipe areas were generally 10cm X 10cm; where wipe areas were known accurately, results were expressed as micrograms (µg) of the metal per square centimeter. The collected bulk materials or wipe(s) were placed in clean, labeled centrifuge tubes. Samples were submitted to DataChem Laboratory of Salt Lake City for analysis via Inductively Coupled Plasma (ICP), NIOSH Method 7300 (modified), ICP Panel B. This analysis quantifies the 27 metals listed in the data tables.

3.10 Surface Dust Allergens

Surface dust was collected from carpet surfaces into a sock filter (provided by the analytical lab) placed in the wand of a standard vacuum cleaner. Vacuuming continued until approximately one teaspoon of fine dust was collected. This normally took about five minutes per sample, and each sample represented several square feet of surface area. The dust samples were submitted to IBT Reference Laboratory of Lenexa, Kansas, for analysis of fungi (type and prevalence) and cockroach and dust mite allergens.

Fungal spores from the collected dust were cultured on malt extract agar plates and the mold genera were determined in "colony forming units" per gram of dust (CFU/g). The analytical reports provided by IBT list mold genera in decreasing order of prevalence. IBT has provided guidelines based upon CFU/g levels ranging from "Very Low" to "Extremely High" and these guidelines have been used for placing measured levels in perspective.

Dust mite (*D. farinae & D. pteronyssinus*) and cockroach (American/German) allergens were analyzed via the monoclonal based immunoassay method. Levels of these allergens are reported in units of micrograms per gram (µg/g) of total dust. IBT has again provided guidelines for interpreting the levels measured. They list a threshold value and exposure category (low, moderate, high) for each allergen. They recommend that allergen levels be controlled down to the threshold level or as low as possible, but caution that, "since patient sensitivity may vary considerably, there is no ideal target appropriate for all patients."

3.11 Lead-Based Paint

Measurements of lead in paint were made using a Radiation Monitoring Devices, Inc. (RMD) LPA-1 X-ray Fluorescence (XRF) Spectrum Analyzer. The LPA-1 Lead Paint Analyzer non-destructively measures lead concentrations of painted surfaces over the range of about 0.3 to >10 mg/cm^2. The RMD does not generate inconclusive readings and no substrate correction is required, as is the case for older types of XRF analyzers.

The LPA-1 system includes three main components: (1) the LPA-1 analyzer, which is a portable analytical instrument operating on the principles of X-ray fluorescence; (2) forms for recording of field data; and (3) report generation software, which allows for rapid generation of data tables.

At the beginning and again at the end of each day's testing, the calibration of the LPA-1 was checked by taking three or more consecutive measurements on a lead free control block surface and three or more consecutive measurements using a red 1.02 mg/cm^2 National Institute for Standards and Technology (NIST) Standard Reference Material paint film over the control block. The calibration values obtained were compared to the calibration check tolerance values on the XRF Performance Characteristic Sheet for the instrument to ensure that it was operating within the stated tolerance limits.

Field data forms were used to manually record information about individual XRF measurements. This information includes the sequential XRF sample number, room number, the building component (e.g.. wall, ceiling, baseboard, door, etc.), component substrate (wood, drywall, plaster, concrete, brick, metal), and paint color and condition. The electronically stored data were downloaded, and the field notes were used to enter sampling parameters. The RMD software was then used to generate data reports.

4.0 Air Monitoring Results

4.1 Volatile Organic Compounds

Volatile organic compounds (VOCs) were measured using the Carbotrap collection-GC/MS analysis method described in Section 3 above. Copies of DataChem's analytical reports for all VOC samples can be found in Volume II, Tab A.

A total of 32 VOC samples were obtained, including 25 samples in indoor locations, 5 samples in outside air, and 2 field blanks. Of the indoor VOC samples, 10 were collected in the 1-NW quadrant. Due to the voluminous size of the VOC data and data analysis tables, they have been placed in Appendix A of this report. Those tables are as follows:

Table V.1 VOC Air Sampling Locations, On/Off Times, and Air Volumes
Table V.2 Carbotrap-GC/MS Analytes and Practical Quantitation Limits
Table V.3 VOC Sampling Results, All Samples

Table V.1 presents sample collection data for each VOC sample, including location, on/off times, and air flow rates. Sample air volume was calculated from these data and were used in Table V.3 to calculate air concentrations.

Table V.2 lists the analytes that are measured by the Carbotrap method and the Practical Quantitation Limit (PQL). All 51 Target compounds have an entry of 25 ng in the PQL column; other compounds are those that typically appear in the "non-target" compound list. Assuming an air sample volume of 25 liters, the PQL for all target compounds is 0.001 mg/m^3. The DataChem analytical reports list analyte quantities that are less than the PQL, but these are flagged with the letter 'J' indicating that the compound is present at greater than the Minimum Detection Limit (MDL) but below the PQL. We have included all 'J' analytical results in the data tables and have treated them as "real" values, even though there is some uncertainty in the precision of the method below the PQL.

Table V.3 presents the full results for all 32 VOC samples and blanks. Note that each table is two pages in length and contains multiple samples. The units in the "Found" column of Table V.3 are nanograms (ng); a nanogram is 1 billionth of a gram. Air concentrations of contaminants are expressed in milligrams per cubic meter of air, which is obtained by dividing the mass of each analyte by the sample volume found in Table V.1. The individual analytes are entered by "chemical family" (e.g., alkanes, aromatics, halocarbons, aldehydes/ketone, etc.) and summed by chemical family. The total of all analytes appears in the bottom row of each two-page table under "Total VOCs." The column headed "Guide Value" refers to the "target guideline value" for each chemical family and total VOCs (TVOC) recommended by Seifert[1]. Based upon considerable experience and research, Seifert has proposed target guideline values for various classes of organic compounds in air, and a total VOC level of 0.3 mg/m^3. These values are not based upon toxicological considerations, but reflect achievable indoor levels,

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[1] Seifert, B. Regulating Indoor Air. In: Indoor Air '90, Proceedings of the 5th International Conference on Indoor Air Quality and Climate, Volume V, p. 35. Toronto, 1990.

which, if met are unlikely to result in indoor air quality complaints or symptoms. The OSHA Permissible Exposure Limit (PEL) is also listed (in mg/m^3) for those chemicals for which OSHA has a published worker exposure standard.

Two field blanks were submitted, one prepared on Tuesday and one on Friday. These tubes were opened briefly, were recapped, packaged and submitted in the same way as the samples. Data for the field blanks may be found in the last two pages of Table V.3. The blanks showed only very low levels of contamination, and were judged to be entirely acceptable, based upon previous experience with the Carbotrap GC/MS method.

4.1.1 VOC Sampling Results

Table 4.1 presents summary data, including the subtotal for each chemical family and total for all VOCs (TVOC) for all 30 samples, organized in three groups: the 10 samples in the 1-NW quadrant, 15 samples in other indoor locations, and 5 samples taken in outdoor air.

VOCs in Quadrant 1-NW
As shown in Table 4.1, the arithmetic mean of TVOC values for the 10 VOC samples taken in the 1-NW quadrant was 0.186 ± 0.081 mg/m3. The maximum TVOC value was 0.393 mg/m3 and the minimum was 0.112 mg/m3. While the data are probably best described by a lognormal distribution (geometric mean = 0.174 mg/m3), the arithmetic mean is a reasonable estimate of central tendency and exceeds the geometric mean. We have therefore chosen to use arithmetic means in summarizing the data.

VOCs in Other Indoor Locations
The arithmetic mean TVOC values for the 15 samples taken in indoor locations other than the 1-NW quadrant was 0.145 ± 0.050 mg/m^3. The maximum TVOC value was 0.284 mg/m^3 and the minimum was 0.104 mg/m^3. The geometric mean of TVOC values was 0.139 mg/m^3.

Outdoor Samples
The mean TVOC for the 5 outdoor samples was 0.078 ± 0.021 mg/m^3; the maximum was 0.113, the minimum 0.061, and the geometric mean 0.076 mg/m^3.

4.1.2 Data Analysis

Statistical Analysis of Data
As stated in Section 2.2.3, one of the goals of the investigation was to determine whether differences existed in VOC levels in the problem area, 1-NW, as compared to other areas of the building. Several tests of the null hypothesis that VOC levels in 1-NW were equivalent to VOC levels in other areas of the building yield borderline results (See Appendix C). Three acceptable statistical tests fail to reject the null hypothesis at a 5% significance level and one acceptable statistical test does reject the null hypothesis at a 5% significance level. In all four cases, the results are borderline on one side or the other of the 5% p-value.

The second null hypothesis was that levels were not elevated above consensus standards or guidelines or above "expected" levels. In the case of VOCs we have tested the indoor TVOC data for all locations against Seifert's Target guide of 0.3 mg/m^3 and find that the second null hypothesis is not rejected, at a 1% significance level. The conclusion is the same when testing only the 1-NW indoor TVOC data against the Target Guide.

The third null hypothesis, that indoor levels were equivalent to outdoor levels, was rejected at the 95% confidence interval. Levels indoors were thus significantly higher than those in outdoor air, as is typical in office buildings.

Variability With Day of Sampling
Perusal of the VOC data suggested that VOC levels varied with date of sampling. We therefore sorted the data by day of sampling to assess this apparent trend. Table 4.2 shows how indoor and outdoor VOC levels varied over the 5 days of sampling. These data are presented graphically in Figure 4.1. It is apparent from Figure 4.1 that the high TVOC value on Monday is due largely to the halocarbon component, and the moderately high TVOC value on Tuesday is due mostly to elevated alkanes. Without the contribution of these two components on Monday and Tuesday, there would be no apparent trend in TVOC values. Figure 4.2 shows the day-to-day variability in the VOC data for the outdoor samples. The outdoor TVOCs were uniformly lower than concurrent indoor samples and were dominated by halocarbons and alkanes. There was no apparent pattern to the outdoor results.

4.1.3 Discussion

The indoor TVOC levels are very low with respect to occupational exposure standards; the ratios of the measured values to the Threshold Limit Values or Permissible Exposure Limits range from about 10^{-3} to 10^{-6}. One sample (514-V-02, taken in Office C, 1-NW) exceeds Seifert's TVOC target guideline of 0.3 mg/m^3, but it should be remembered that these guidelines are not based upon toxicology, but rather relate to complaint and comfort issues. Closer examination of this highest sample (see Table V.3 and DataChem analytical report for this sample) indicates that the chemicals at highest concentration were long-chain alkanes (C14 to C17), which accounted for 0.121 mg/m^3, and Freon 11, which accounted for 0.084 mg/m^3 of the 0.393 mg/m^3 total.

The source of these long-chain alkanes at Building 807 is unknown, but they are sometimes found in liquid toners used in copy machines, and are components of kerosene and heavier petroleum fuels. They have high boiling points (250 to 300 °C) and low vapor pressures, and are generally of low toxicity. Freon 11 (trichlorofluoromethane), also known as Genetron 11, is a commonly used refrigerant. It may be in use in systems in Building 807, but this was not verified. Like other "Freons," it is of relatively low toxicity, with a Ceiling TLV of 1,000 ppm.

It is possible that weekend shut-down of the HVAC systems allows some accumulation of VOCs (such as refrigerants and alkanes), resulting in the higher concentrations of these compounds early in the week.

Indoor VOCs were uniformly higher than outdoor levels, indicating that the building does add VOCs to the background air. While VOC levels in the 1-NW quadrant averaged higher than those in other indoor quadrants, the difference was not statistically significant at the 95% confidence interval.

4.2 Formaldehyde

DataChem's analytical reports may be found in Volume II, Tab B. The limit of detection of the analytical method is reported as 0.3 µg formaldehyde per sample, which provides sensitivity down to about 10 ppb. Formaldehyde samples were co-located with most VOC samples.

Table 4.3 presents results of formaldehyde sampling. None of the 19 samples (14 indoors, 4 outdoors, and 1 field blank) showed detectable levels of formaldehyde. At the sample air volumes used, this generally equates to air concentrations that were less than 0.005 ppm. One sample (514-F-05) had a smaller air volume due to a pump fault, and this sample showed less than 0.012 ppm formaldehyde.

The formaldehyde levels in Building 807 are lower than those typically encountered in office buildings. This may be due to several factors: there is a lower proportion of carpet and fabric goods than typically found in office buildings (many spaces are uncarpeted and there are few office cubicles); there were no recently installed areas of carpet and essentially no new furnishings; the occupant to internal volume ratio is lower than most office buildings.

The World Health Organization lists 0.06 ppm formaldehyde and below as being the concentration of "limited or no concern." We therefore conclude that formaldehyde levels in the building at the time of this sampling were entirely acceptable and of no concern with regard to health impacts. The OSHA PEL for formaldehyde is 0.75 ppm, 8-hour TWA, with a STEL of 2.0 ppm. The Threshold Limit Value (TLV) published by the American Conference of Governmental Industrial Hygienists (ACGIH) for formaldehyde is a Ceiling of 0.3 ppm.

4.3 Carbon Dioxide, Total Particulate, Temperature, and Relative Humidity

Carbon dioxide, temperature and RH measurements were taken at the same sampling locations where VOC/formaldehyde samples were taken. The readings were taken once in the morning and again in the afternoon at each sampling location.

Table 4.4a and 4.4b present all CO_2, temperature, relative humidity, and particulate data for indoor and outdoor locations, respectively. The overall average for all 50 indoor CO_2 measurements was 457 ± 58 ppm, with a maximum of 638 ppm; the average of 10 outdoor readings was 383 ± 53 ppm, with a maximum of 490. The indoor values are well below the ASHRAE guideline of 1,000 ppm and indicate excellent outdoor air ventilation. It should be remembered, however, that the first floor was unoccupied at the time of this investigation, and this would help to depress measured CO_2 levels.

Temperature indoors average 72.8 ± 1.1°F; concurrent outdoor temperatures were 75.1 ± 2.3°F. Relative humidity indoors averaged 29.6 ± 10.8% with a high of 49.3%. Outdoor RH averaged 27.3 ± 13.2% with a high of 48.3%. The indoor temperature/RH regime can be compared to the guidelines set forth in ASHRAE Standard 55-1992, *Thermal Environment Conditions for Human Occupancy*. When these ASHRAE guidelines are met, most building occupants (at least 90%) should be satisfied. The guidelines are summarized in the table below. The recommended temperature ranges vary with season, because the weight of clothing varies. While temperatures as high as 79°F are acceptable in summer, they are too warm for comfort when occupants are wearing winter clothing.

The temperatures measured in this investigation were within the ASHRAE comfort guidelines. Relative humidity was also generally within the acceptable range.

Airborne particulate (total dust) levels averaged 0.017 ± 0.012 mg/m^3, with a maximum of 0.070 mg/m^3. These levels are within the normal range of dust concentrations in occupied buildings.

Optimum and Acceptable Ranges of Operative Temperature for People During Light, Primarily Sedentary Activity, at 50% Relative Humidity and Mean Air Speed =0.15 m/s.
(ASHRAE Standard 55-1992)

Season	Description of Typical Clothing	Optimum Operative Temperature	Operative Temp. Range (10% dissatisfaction criterion)
Winter	Heavy slacks, long-sleeve shirt and sweater	71°F (22°C)	68 – 75°F (20 – 23.5°C)
Summer	Light slacks and short-sleeve shirt	76°F (24.5°C)	73 – 79°F (23 – 26°C)

4.4 Organophosphate Pesticides

Results of sampling for organophosphate pesticides are presented in Table 4.5. None of the 10 samples taken in the building showed detectable levels of any of the 11 pesticides included in the scan. Using the analytical limits of detection and sample air volumes collected, this equates to concentrations generally below 10^{-4} mg/m^3. Threshold Limit Values (TLVs) for these pesticides range from 0.1 to 10 mg/m^3, as detailed in the table. The DataChem analytical reports may be found in Volume II, Tab C.

4.5 Acrylamide

Air sampling results for acrylamide are presented in Table 4.6. All samples showed less than detectable acrylamide. Owing to the relative insensitivity of the sampling method and analysis, the limit of detection was marginally above the TLV of 0.03 mg/m^3. There was, however, no evidence of use or sources of acrylamide within the building. The DataChem analytical reports may be found in Volume II, Tab D.

4.6 Bioaerosol Monitoring

Bioaerosol monitoring in Building 807 consisted of Spore Trap and Culturable Mold Spore sampling. The spore trap methodology makes use of Zefon Air-O-Cell™ cassettes, as described in Section 3. This method quantifies spores in air and speciates them based upon morphology. Many mold spores have distinctive color, size, and shape and these positively identify a mold species. Other spores, however, such as those for *Aspergillus* and *Penicillium* have very similar appearance and do not allow this speciation. The spore counting method quantifies all airborne spores, whether viable or not. This is of value since spores containing toxins (for example, *Stachybotrys chartarum* or *atra*) are of concern whether living or dead.

The culturable method (Anderson N-6 impaction on agar plates, also described in Section 3) quantifies only viable spores (those that will grow on culture plates) and allows speciation of mold with similar appearing spores. The two methods thus are not equivalent and results from each cannot be directly compared, but taken together, provide a more accurate picture of airborne mold spore levels.

4.6.1 Bioaerosol Sampling Results

Table 4.7 presents summary results for all bioaerosol samples. Four spore trap (3 indoors and one outside) were collected on each of the five days of sampling. Three culture samples were taken each day, two indoors and one outside; these were co-located with the spore trap samples. The analytical reports from Environmental Microbiology may be found in Volume II, Tab E. These provide detailed species and count data for each sample as well as charts presenting the spore trap data. Total spore counts ranged from 13 to 1,333 spores/m^3 in indoor air, and from 279 to 1,093 spores/m^3 in outdoor air. On two sampling days (5/14 and 5/18) total spore counts for an indoor sample exceeded the concurrent outdoor spore counts. Sample 514-AC-1, taken in Room J, 1-NW, found 1,040 spores/m^3, while the outdoor sample (514-AC-4) measured 626 spores/m^3. Sample 518-AC-1 measured 1,333 spores/m^3, while the outdoor sample (518-AC-4) showed 280 spores/m^3.

The culturable mold samples taken indoors ranged from <12 to 108 colony-forming units per cubic meter (CFU/m^3), while outdoor samples ranged from 12 to 154 CFU/m^3. Indoor samples showed lower CFU/m^3 counts than did outdoor samples on all days except Monday, where the outside level was 36 and indoor levels were 60 and 82 CFU/m^3.

Table 4.8 organizes the spore trap data by sampling area to allow comparison of total spore levels in the 1-NW quadrant to those collected in other areas of the building and in outdoor air. Total spore counts in the 1-NW quadrant averaged 455 ± 511 spores/m^3. The outdoor average was higher at 517 ± 354 spores/m^3, while the average of counts in indoor locations other than 1-

NW was considerably lower, at 54 ± 55 spores/m^3. The 1-NW and outdoor values were not significantly different at the 95% probability level, but the "other location" indoor samples were significantly lower than the 1-NW and/or the outside samples.

4.6.2 Discussion

There are currently no legal standards in the United States governing mold levels in air or on surfaces. Many guidelines and recommendations have been proposed, however, and these were recently reviewed in a publication by Rao[2]; a copy of this article has been included in Appendix D. Existing guidelines are based upon ratios of indoor and outdoor levels, as well as absolute magnitude of total counts (regardless of species), and many include levels of concern for certain recognized toxigenic species. Most guidelines suggest that indoor levels should be lower than outdoor levels, although some state that indoor levels must be greater than outdoor levels by a factor of 10 to be of concern. It is recognized that there can be great variability in spore levels due to true variation as well as to sampling error.

Most of the guidelines specify levels in CFU/m^3, meaning that they are based upon viable or mold culture sampling and analysis, and levels are generally considered normal unless they exceed values of 100 to 1,000 CFU/m^3. Separate guidelines are sometimes given toxigenic species; the New York City guidelines for *Stachybotrys* suggest that levels above 100 CFU/m^3 may be of concern. One guideline (Lacey, et al) states levels in spores/m^3, and states that levels of 1,000 to 10,000 are normal in air. A synopsis of the current ACGIH recommendations on interpretation of fungal sampling results has been attached in Appendix D.

The airborne spore data obtained in this study (through both viable and non-viable methodology) compare favorably with existing guidelines; indoor culture sample levels were low, ranging from <12 to 108 CFU/m^3, and outdoor levels ranged from 36 to 154 CFU/m^3. Non-viable spore counts were higher, as is normally the case when side-by-side sampling in conducted using both methods. The airborne spore counts were not elevated above guidelines in an absolute sense, but indoor levels were higher than concurrent outdoor levels on two days.

On two days, 5/14 and 5/18, the non-viable spore count results in the 1-NW quadrant showed higher counts indoors than outdoors, due to elevation in *Penicillium* and/or *Aspergillus* spores. The culturable results did not show this pattern, however. The culturable results also showed different species than the non-viable spore samples. *Penicillium/Aspergillus* was not found on the corresponding culture sample on 5/14; on 5/18 the corresponding culture sample found small amounts of *Penicillium* and *Aspergillus*.

Based on average levels over the week, outside spore counts were higher than those in 1-NW, but the two groups were not statistically different. It is of interest, however, that the spore counts in indoor locations other than 1-NW were significantly lower than those in 1-NW.

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2 Rao, CY, HA Burge, JCS Chang. Review of Quantitative Standards and Guidelines for Fungi in Indoor Air. J. Air Y Waste Manage. Assoc. 46:899-908, 1996.

One possible explanation for these findings is that past flooding in 1-NW resulted in growth of *Penicillium* and *Aspergillus*. Spores were released in the flooded areas and settled to carpeting and possibly other porous surfaces. These spores can be re-suspended through activity in these rooms, resulting in higher counts. (During the investigation, considerable activity occurred in many of the rooms sampled—ceiling tiles were removed in some rooms, HVAC systems were opened and considerable foot traffic occurred. These activities may have re-suspended spores and dust from a variety of locations.) It is possible that the settled spores have aged to the point that they are no longer viable and therefore do not show up on the culture samples.

There was no indication at the time of the investigation that active mold growth was occurring at any location in the building. No "moldy/mildewy" odors were noted, and all surfaces appeared to be dry. Ceiling tiles showed evidence of staining in only a few locations at the time of the investigation, although it was reported that new ceiling tiles had been installed during the last year. No *Stachybotrys chartarum/atra* was found in any sample, and toxic species of *Penicillium* (*expansum*) and *aspergillus* (*fumigatus*, *flavus*, and *niger*) were found on only a few samples at very low counts.

4.7 Airborne Mercury Screening Survey

A screening survey was performed to assess airborne concentrations of elemental mercury vapors throughout the building, with emphasis on laboratory areas. A total of 330 measurements were taken throughout the building using the Jerome X431 mercury monitor. Monitoring locations included "breathing zone" samples (4 to 5 feet above floor level) and samples taken near floors, within cabinets, under fume hoods, or in other "out of the way" locations to determine whether mercury contamination might be present.

As shown in Table 4.9, only three of the 330 samples showed readings other than zero. These were two locations in Room 3003 (3-SE), under the fume hood, 0.010 mg/m^3, and inside the fume hood, 0.007 mg/m^3. The other non-zero sample was in Room 3006 (3-SE), general area, where a reading of 0.005 mg/m^3 was obtained. Since the vast preponderance of samples throughout the building showed reading of zero, no attempt was made to analyze the data statistically.

5.0 Surface Contaminant and Bulk Materials Sampling

5.1 Surface and Bulk Dust Collection for Metals

Sampling was conducted to determine levels of metals on a variety of surfaces in Building 807. Samples of surface dust were collected using three different methods: wipe sampling, bulk dust collection, and vacuum collection. Some bulk materials were also collected, including insulation and filter materials. These samples were all analyzed by DataChem Laboratory for a panel of 27 metals by ICP analysis, as described in Section 3. All of the DataChem ICP analytical reports may be found in Volume II, Tab F. (In addition to these ICP-metals samples, surface and paint-chip samples were collected for lead; these are described in Section 6 of this report.) Five of the ICP metals were identified in the Phase I literature search as being neurotoxins: arsenic, cadmium, manganese, lead, and thallium.

Sampling for metals on surfaces was performed to satisfy concerns about both current and past exposures. Settled dust on accessible surfaces could lead to employee exposures and, depending upon the “age” of the settled dust, could be indicative of past release and deposition of metals. Surfaces with thick accumulations of dust were sought out, with the rationale that these might represent dust deposition going back some years. It was not possible, however, to determine time periods represented by this dust. There are no records or recollections as to when cleaning on such surfaces last occurred.

It was discovered that quite thick (>1/16th inch) accumulations of dust were present on the upper surface of fluorescent light fixtures throughout the facility. The light fixtures suspend from the ceiling on pendants about 18 inches in length, so there is ample opportunity for dust to settle on the upper horizontal surface. The fixtures are high enough that building occupants would not see or contact the upper surface, except under unusual circumstances. These dust accumulations were felt to be particularly useful since this deposition occurred within the occupied space of the building and would therefore represent dust supplied by the HVAC system or generated by activities within each office or laboratory.

Dust deposition could also be found in the ceiling plenum above the drop-tile ceiling, on the tops of ductwork, and on other horizontal surfaces. These surfaces could be influenced by dust in return air traveling through the plenum to the return air ducts, and may be less closely tied to a specific room or laboratory, however. Dust samples were also collected from interior surfaces of the HVAC systems, including major and minor supply ducts, mixing or VAV boxes, fan units, Induction units, and supply registers. Several samples of filter materials were also taken—these included the filter materials added to the discharge louvers on Induction units and the return air filters in the Induction fan housing. And finally, a few samples were taken of the insulation materials inside of the metal wall system in Room G in the 1-NW quadrant. These were taken to determine whether the insulation materials contained appreciable metal content, or had perhaps become contaminated with dusts containing metals.

5.1.1 Sampling Results

Table 5.1 presents results for the settled dust collected from the horizontal top surface of fluorescent light fixtures at nine (9) locations in the building. The values listed in the table are micrograms of metal per gram of dust (µg/g), equivalent to parts per million by weight. Several samples demonstrated metal levels that were elevated well above other samples in the set. Two samples (518-2NE-2039A-LF and 518-3SW-3104-LF) appeared to have elevated levels of a broad range of metals, including: Be, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Te, V, and Zn; levels in 2039A were considerably higher for some metals than those in 3104. Sample 518-1SW-D1085-LF appeared to be elevated in Pb, at 960 ppm. Sample 518-3SW-3113-LF was the only sample among these nine that showed measurable Thallium (Tl) at a concentration of 220 ppm; this sample also showed elevated yttrium, Co, and Be. None of the samples showed detectable levels of arsenic (As).

Table 5.2 presents surface metals wipe sampling results; all but one of the 17 samples in the table were taken on internal HVAC system surfaces. Thirteen were taken on air supply surfaces (ducts, mixing boxes, diffusers, etc.) and three ("HVAC-Return") were taken on surfaces within the ceiling plenum, through which return air flows. One sample, 514-1NW-N-LF, was taken on the top surface of a light fixture—these results are not comparable to the bulk light fixture samples shown in Table 5.1 because percent by weight cannot be determine in a wipe sample.

Focusing on the five neurotoxic metals in these samples indicates that arsenic was not detectable in any sample. Cadmium was highest in sample 517-Base-Ifan-F, taken on the discharge side of the Induction fan unit in the basement. Manganese was highest in sample 515-1NW-BC-MB-F taken on the floor of a mixing box in front of Rooms B and C in the 1-NW quadrant. Lead appeared to be elevated in three samples, compared to the other 14 samples in the set: two samples (517-1NE-L-W1 and –W2) taken on horizontal surfaces in the plenum above Room L in the 1-NE quadrant showed 680 and 870 µg lead per sample. Sample 515-1NW-BC-MB-F also showed elevated lead, at 350 µg/sample. Only one sample, 517-Base-Ifan-F, showed detectable levels of Thallium, at 2.8 µg Tl per sample.

Table 5.3 presents results for samples collected via the vacuum method and analyzed for metals via ICP. The vacuum method was used on irregular or difficult to access surfaces, where wipe sampling and bulk collection were not feasible. These included internal surfaces on Induction heater units (those with the suffix "IU"), a carpet sample, and a sample from inside the Induction fan unit in the basement. Also included with these samples are analytical results for a bulk dust sample collected in January, 2000, from the Induction heater screen in Room N by Sandia personnel (J-2000-N-IU).

Arsenic and thallium were not detected in any of these samples. Cadmium ranged from 12 to 49 ppm, manganese from 69 to 270 ppm, and lead from 180 to 510 ppm. These ranges are reasonably "tight" and it does not appear that any sample is unusually elevated.

Table 5.4 presents metals concentrations in air filter and insulation materials. The analytical lab has reported varying limits of detection on these samples due to interferences and dilutions that had to be made in analysis. None of the samples showed measurable arsenic, although the detection limit in the filter samples rose to 90 ppm. No measurable thallium was found (the detection limit was 50 ppm for one sample). Cadmium appeared to be low; one sample had a high detection limit of 200 ppm due to interferences and dilution by the laboratory. Lead appeared to be low in all samples. Manganese ranged from 37 to 1000 ppm in the filter samples and from 750 ppm in fiberglass insulation to 1900 ppm in the rock wool insulation.

5.1.2 Discussion

Perhaps the most interesting finding in the surface metals portion of this investigation was the discovery of a fairly thick layer (>1/16th inch) of accumulated dust on the tops of light fixtures throughout the building and the variability in metals content of this dust. While we can only speculate as to the deposition history and the "age" of this dust, its thickness would suggest at least several years accumulation. This dust is thought to have two possible sources: 1) dust supplied by the ventilation system serving each room (the overhead supply from the East and West main air handlers, and, in perimeter rooms the Induction system) and 2) dust generated by operations occurring within each room, and to a lesser extent, nearby rooms. Dust from light fixtures in Rooms 2039A and 3104, which have had histories of lab work, including metal machining, had metal concentrations markedly elevated from other samples in this set. The dust sample from Room 3113 (reportedly a lab that grew crystals and did research in high temperature superconductors) was the only one to show measurable thallium. The only elevated level of a neurotoxic metal in an office space was in Room D1085, where the lead level was 960 ppm, compared to a range of 200 to 400 ppm in other office spaces.

It is not possible to determine how these elevated metal levels in settled dust relate to employee exposures within the building or within specific rooms. The elevated metal content could be due to discrete or intermittent events that resulted in short-term generation of metal dusts or fumes, or could be due to longer-term, low-level generation. The levels measured are not so high as to suggest that any significant exposure occurred to these metals over the long-term. Experience in industries that work with lead suggests that settled dust in production areas would have similar lead content to the materials used in production. High levels of lead in settled dust do not necessarily equate to high worker exposures. These findings are intriguing, however, and there may be some value in collecting and analyzing settled dust in additional building locations while this material is still available.

Bulk dust samples collected by the vacuum method on internal surfaces of the Induction HVAC system (and one from carpeting) did not show the degree of elevation in metals found in the settled dust samples in laboratories. In general, these samples mirrored levels found in the office dust samples.

Dust within the main HVAC systems (East and West systems) were not thick enough to allow bulk collection, so wipe sampling was performed. The results of wipe sampling cannot be directly compared with bulk analysis, but must be expressed as a surface loading value (mass per unit area wiped). In general, the levels of metals within the HVAC systems were not elevated above expected levels, and it does not appear that unusual or unexpected metal concentrations exist within these systems. Air filter materials and insulation samples likewise do not appear to show unusual or unexpected levels of metals.

5.2 Surface Allergens

5.2.1 Dust Mite and Cockroach Allergen Sampling

Table 5.5 presents results for all surface dust sampling for dust mite allergens (*D. farinae/D. pteronyssinus*), cockroach allergens (*American/German*), and mold. These samples were taken in offices areas and analyzed for dust mite and cockroach via polyclonal based immunoassay and viable fungal spores. Copies of the IBT Reference Lab Reports may be found in Volume II, Tab G.

Levels of dust mite allergens ranged from <1.6 to 2.1 micrograms per gram (µg/g) of dust. The threshold levels for dust mite allergen is listed by IBT as 15 µg/g. The measured levels are well below the threshold and are categorized as low.

Cockroach allergen levels ranged from <2.5 to 21.7 µg/g. Two samples were above the threshold of 5 µg/g: sample 515-1SE-1024-F had 6.6 µg/g and was classified as Moderate; sample 516-1NW-J-F showed 21.7 µg/g and classified as High.

5.2.2 Culturable Mold in Dust

Concentrations of viable fungi in dust ranged from 11,000 to >2,500,000 colony forming units per gram of dust (CFU/g). As shown in the IBT interpretive guideline, values from 10,000 to 100,000 are considered Moderate, from 100,000 to 1,000,000 as High, and >1,000,000 as Extremely High. As shown in Table 5.5, sample 516-1SW-AQ-F fell in the Extremely High category. This sample was taken in the corridor near the doorways leading to Rooms A and Q in the 1SW quadrant. The samples collected in Rooms O and W in the 1NW quadrant ranked as High, while seven samples were categorized as Moderate.

5.2.3 Discussion

Levels of cockroach allergens and mold were high to extremely high at a few locations in the building. It should be borne in mind, however, that no cleaning or vacuuming had occurred prior to this study for a protracted period of time. There was no evidence of current or historical problems with cockroaches.

There have been historical reports of water leaks and flooding in offices areas with 1-NW. However, at the time of this investigation, there was no evidence of moisture on carpets and no odors suggestive of mold growth. It could not be determined whether the high mold concentration in dust collected in 1SW near offices A and Q was due to past flooding and growth of mold in this area or due to some other mode of contamination by fungal spores. It is not possible to equate these surface findings with airborne exposure to mold spores. The mold species identified in these samples occur commonly in outdoor and indoor environments, and are not known to be especially toxigenic.

6.0 Lead-Based Paint Survey

6.1 Background

Building 807 was completed prior to 1978, and therefore has the potential to contain significant quantities of lead-based paint (LBP). Since lead is a known neurotoxicant, it was decided to screen the buildings for LBP. LBP in good condition poses no hazard of exposure, except to maintenance personnel who might disturb the paint in the course of their work. Deteriorated lead paint can produce a potential for exposure if lead-containing dust is present on accessible surfaces. In addition to performing an in-site lead inspection using the XRF analyzer (See Section 3), wipe sampling of floors was conducted throughout the building and 10 paint chip samples were collected for laboratory analysis for lead via atomic absorption spectroscopy.

The LBP Inspection was conducted over the period of May 14-16, 2001, and it closely followed the inspection protocol defined by the U.S. Department of Housing and Urban Development (HUD) *Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing* (HUD Guidelines), 1997 Revision, with appropriate modifications for a non-residential building.

HUD considers paint to be lead-containing if the lead concentration is 1.0 milligram per square centimeter of surface area (1.0 mg/cm^2) or greater, or if the lead concentration is greater than 0.5% by weight. The Consumer Product Safety Commission (CPSC) currently considers paint to be lead-containing if the concentration of lead exceeds 600 ppm (0.06% by weight) in the pre-applied paint product. In 1978, the CPSC banned the sale of lead-based paint to consumers and its application to areas where consumers have direct access to painted surfaces. For this reason, lead-based paint surveys are generally limited to buildings constructed prior to 1978.

6.1.1 XRF Sampling Results

The Sequential and Summary Reports of Lead Paint Inspection produced by the XRF software for this survey are located in Appendix B to this Volume. These tables present all LBP XRF data obtained in the inspection, organized by day of sampling and in sequential order. The Summary Reports list only those samples showing readings of 1.0 mg/cm^2 or greater. During the three days of the LBP survey, 72 calibration readings were taken, all indicating that the XRF was within the accuracy tolerance limits specified by HUD. Of the 873 XRF measurements made during this survey, 20 measurements were at or above the HUD Guideline criteria of 1.0 mg/cm^2. Table 6.1 shows these 20 "positive" samples. Values ranged from 1.0 to 6.7 mg/cm^2. Four samples on the first floor on painted metal components measured 1.0 mg/cm^2. These surfaces appeared to be identical to other surfaces throughout the first floor that were all below 1.0 mg/cm^2. Two measurements on red metal doors in the basement were also at 1.0 mg/cm^2. It is not unusual for a small percentage of XRF measurements on non-lead surfaces to yield values at or around 1.0 due to random error, particularly on metal substrates. Chip sampling (discussed below) was conducted on similar surfaces in the building to help determine whether these readings were accurate or spurious.

One surface in the 2-SW quadrant, a green metal cabinet door, showed 6.3 mg/cm^2; a second confirmatory reading showed 6.5 mg/cm^2. It is very likely that this surface is a true positive, since levels were well below 1.0 mg/cm^2. Several surfaces in mechanical areas of the basement were positive for lead-based paint, including tanks, machine guards, and other painted metal surfaces. It is not unusual for this type of equipment to be primed with "red lead" primer or to be painted with LBP.

Four exterior surfaces were positive for LBP, including railings, a tank holder, and a post on the loading dock. The only non-metal surface showing positive LBP was the wood tank holder on the loading dock.

Paint surfaces throughout the building were generally intact and free of damage; only three components were categorized as in poor condition, but these were all non-lead paint.

6.1.2 Paint Chip Sampling Results

Table 6.2 present results of paint chip sampling. Ten one by two inch paint samples were cut, throughout the building and these were submitted to EMSL Laboratory for analysis of lead via atomic absorption spectroscopy. EMSL's report can be found in Volume II, Tab H. Lead concentrations in the paint chips ranged from 0.015 to 0.132 % by weight. HUD's criteria for lead-based paint on a weight percent basis is 0.5% lead or greater. Thus, none of the paint chip samples would be categorized as LBP under HUD criteria. Five of the samples exceeded the Consumer Product Safety Commission's definition of lead-free paint of 0.06% by weight, however. The surfaces chip sampled represented the vast majority of paint throughout the facility, based upon homogeneity of component, substrate, and color.

6.1.3 Lead Wipe Sampling Results

A total of 24 wipe samples for lead were collected on hard floors, fixtures, cabinets, and shelves in accessible locations on the first through third floors. The wipe samples covered areas of 0.69 to 1.0 square feet. Lead analysis was performed by EMSL; their report is included in Volume II, Tab H. Lead concentrations ranged from non-detectable (<10 µg/ft^2) to 1017 µg/ft^2. Seventeen samples had non-detectable lead. The highest value was found on sample 518-1-NE-O-W7 on a ceiling light fixture. This surface had a thick accumulation of dust. There is no published lead surface standard for these types of surfaces.

One sample (518-3-SE-3013-W24) showed a floor lead level above the current HUD/EPA recommended residential lead level of 40 g/ft^2; however, it should be noted that this level is meant to protect small children in residential settings from readily accessible lead dust; it is not directly applicable to inaccessible surfaces in commercial or office spaces where children are not present.

6.1.4 Discussion

Except for a few exterior and mechanical room equipment surfaces, Building 807 is largely devoid of lead paint. Only one surface was found throughout labs and offices in the building that contained lead paint—this was a green metal cabinet in Room 2100. The majority of LBP surfaces were found in basement mechanical areas or on exterior railings and posts. Paint surfaces were generally in good condition throughout the facility. It thus appears unlikely that lead dust is being added to the building environment as a result of LBP.

Wipe sampling for lead on hard surfaces showed an elevated loading on a ceiling light fixture (consistent with the findings of bulk sampling for metals discussed in Section 5.1.1) and one elevated level on a floor in Room 3013. Room 3013 is a currently unoccupied laboratory space that once performed de-poling of lead-containing ceramics. All other wipe samples showed either low or non-detectable lead levels.

Overall, it does not appear that LBP is a serious issue in Building 807, or that it could have contributed significantly to lead exposures in the building, past or present.

7.0 HVAC Photographic and Video Imaging of HVAC Systems

Owing to concerns about possible contamination within the three HVAC systems serving Building 807, efforts were made to investigate internal surfaces of these systems through direct visual inspection and through use of a video camera probe. Wherever internal HVAC systems could be physically accessed, visual observations were made, still photographs were taken, and wipe or bulk samples were obtained. The results of all sampling within the HVAC system have been presented in previous sections of this report. Visual inspection within air handlers and within accessible supply ductwork showed relatively clean surfaces, given the age of the building and the fact that duct cleaning has probably not occurred through the life of the building. Digital photographs were taken within accessible portions of the Induction System and the West air handler. While thin dust coatings were present in ducts and housings, it does not show up in the photos.

A video camera system was provided by Sandia for imaging internal surfaces of ductwork. The camera was about 2.5 inches in diameter and was attached to a stiff cable that allows the camera to be pushed forward into small spaces. The cable is attached to a television monitor and video recorder. The original video tape of the ductwork has been retained at IHI's offices and a copy is in the custody of Johnny Vaughan of Sandia.

Ductwork was opened in the 1-NW quadrant of the building, and the video camera was pushed into the ducting as far as possible. The two overhead air supply ducts (the 10 inch "cold" duct and the 8 inch former "hot" duct) were accessed from their terminal end above Room P. The first section of video tape was taken in the cold duct. We were able to force the camera in about 60 feet before an obstruction was encountered that prevented further penetration. This ducting appeared to be reasonably clean and was free of debris. No visible staining was apparent.

The next section of tape was taken in the Induction system ductwork, feeding the unit in Room P. Due to several right angle bends in this ducting, it was possible to insert the camera only about 20 feet into the duct. No unusual amounts of dust, debris, or foreign materials were observed. We next attempted to image the Induction system ducting from an opening in Room F. It was again impossible to penetrate more than a few feet.

The fourth section of tape is inside the "hot" duct from Room P. The camera was pushed about 75 feet into this duct, which appeared to be quite clean.

The fifth section of videotape was taken in the Induction system in the basement. The camera was pushed up into the main supply duct leading vertically from the Induction fan unit. This round duct bends to the horizontal after rising about 10 feet. We were able to push the camera part way down this horizontal run. Duct work again appeared to be quite clean.

While we were successful in imaging the overhead ductwork serving much of the 1-NW quadrant of the building, we did not have much success in imaging the Induction system ductwork. To accomplish this it may be necessary to obtain a small robotic camera system that is capable of negotiating sharp bends in small ductwork. There are also long stretches of main ducting in the Induction system that could not be accessed from the fan side owing to very long runs of duct. Due to time constraints, no imaging was performed in the East HVAC system. In spite of the limitations of this effort, we found no reason to suspect that the internal surfaces of the HVAC systems in Building 807 are unusually dirty or contaminated. Given the age of the building, the ductwork we could see appeared to be in very good condition.

8.0 Summary Conclusions and Recommendations

As discussed in detail in previous sections of this report, sampling results for VOCs, formaldehyde, organophosphate pesticides, acrylamide, mercury vapor, and lead-based paint were essentially negative, or demonstrated values well below levels of concern. Carbon dioxide, temperature and relative humidity measurements taken at the time of this investigation suggest that the main HVAC systems serving the building are working largely as designed and with reasonable effectiveness. The outside air filter bank on the Induction system, however, is substandard and allows outdoor particulate to enter the building. This system should be redesigned and upgraded as soon as feasible.

Two areas of the investigation demonstrated results of somewhat greater interest; these were results for metals in settled dust and mold spores in air and on surfaces. These are discussed below, along with literature relevant to interpretation of these results.

8.2 Metals

As discussed in Section 5.1.2, metal concentrations in dust on a variety of surfaces (internal HVAC ducts and housings, floors, tops of light fixtures, etc.) were elevated in some areas as compared to others, but it is felt that the levels measured do not pose a hazard to occupants or maintenance personnel. There are no OSHA standards for metals on surfaces—OSHA recommends wipe sampling as a means of determining the effectiveness of controls for hazardous materials and dust in the workplace. They recommend sampling at a variety of locations and comparing the results to determine “hot spots” and thereby determine where controls should be improved. They do not specify absolute standards for concentrations of metals in dust or for surface loading by metals.

HUD has published standards and guidelines for lead levels in dust and soil for residential properties, largely as a means of protecting small children from lead ingestion. The current recommendation is that floor loading for lead should not exceed 40 $\mu g/ft^2$; window sills should not exceed 250 $\mu g/ft^2$. Soil in small high-contact areas where children play (such as sand boxes) should not exceed 400 ppm, but soil in other areas of yards must exceed 2,000 ppm before any action is necessary. These standards are not directly applicable to the non-residential setting, where children are not present. There is no accepted method for determining what lead exposures might occur to office or maintenance workers based upon levels of lead in settled dust.

A case study was found in the literature in which lead surface sampling was conducted in HVAC ductwork in buildings in North Carolina; air samples were also taken and blood lead sampling was conducted on building occupants.[3] Lead concentrations in dust in the ductwork ranged from 764 to 1,654,000 $\mu g/m^2$ in the main building, but no detectable lead was found in the air samples. One window sill had 7,231 $\mu g/m^2$ and floors and work surfaces ranged up to

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[3] Tharr, D, Ed. Survey of Lead Contamination in an Office Building. Applied Occupational and Environmental Hygiene, Vol. 9, No. 6:389-392, 1994.

6,600 μg/m^2. (Note: units of μg/m^2 can be divided by 10.76 to yield μg/ft^2; the HUD floor standard of 40 μg/ft^2 is equivalent to 430 μg/m^2.) In another building in the complex lead was present in ductwork at 766 to 13,235 μg/m^2; floor surfaces ranged up to 1,173 μg/m^2 and air concentrations up to 5.3 μg/m^3 were detected. Blood lead sampling was conducted on 130 of the workers present and no elevation of blood lead was found in any worker. The study concluded that "the risk of lead toxicity for employees working in buildings where similar lead concentrations exist may be minimal."

The lead sampling data obtained in the Building 807 investigation was converted to units of μg/m^2 to allow direct comparison to levels found in the published study. Lead within the HVAC system in Building 807 ranged from 1,600 to 35,000 μg/m^2, which is a much lower range of values than found in the main building of the published study. Lead levels on accessible surfaces in Building 807 (Table 6.3) also indicate lower lead loading than in the North Carolina buildings. Based on this information, it does not appear that lead levels in ductwork in Building 807 would have had any measurable effect on blood lead levels of occupants.

8.3 Mold

As discussed in Sections 4.6.2 and 5.2.3 high levels of mold spores were found in dust collected from carpeting at three of ten locations sampled. Airborne mold spores via the culture method were well within normal limits, but there may have been minor elevations of mold at two locations in 1-NW when measured by the non-viable method. The potential significance of these findings bears further discussion.

8.3.1 Potential for Mold in Building 807

Compared to many other commercial and residential structure, Building 807 contains very little wood or wallboard. Most mold infestations in buildings normally occur when wood and/or the paper surfaces of wallboard become wet through flooding or leaks. Severe problems occur when leaks are chronic and surfaces remain moist for extended periods of time. The internal walls in floors 1 through 3 are essentially all metal, with rock wool insulation. These surfaces are not conducive to mold growth because they provide no nutrients, even if wet. If mold growth were to occur in Building 807, it would be largely confined to cellulose ceiling tiles, stored paper products, and accumulated dust and dirt on surfaces, particularly carpeted surfaces. The carpet present in Building 807 appears to be synthetic and is mostly adhesive backed carpet squares over concrete substrate. Synthetic carpeting does not provide nutrients for mold, but accumulated dust, when kept sufficiently moist, will support fungal growth.

Suspended ceiling tiles can support growth of fungi, but this usually does not result in severe problems for two reasons: 1) when suspended ceiling tiles become saturated, they tend to lose their structural integrity and fall from the support, and 2) when wet temporarily or intermittently, then tend to dry quickly because they have air flow above and below. Significant water leaks above occupied spaces are very noticeable and disruptive, and are quickly addressed in occupied office spaces. The fact that a ceiling tile shows water staining does not mean that significant mold growth has occurred. The experience of IAQ investigators at IHI is that stained tiles typically do not show elevated spore levels when sampled.

For these reasons, Building 807 has a much lower potential for serious mold growth than most typical office buildings. While some localized areas of mold growth could occur on carpeted surfaces (and indeed, probably have), and, under very specific moisture conditions, on ceiling tiles, there is little or no potential for growth behind walls or under carpets and floors.

The HVAC systems serving Building 807 are also not conducive to mold growth, and no evidence was found of water problems affecting inner surfaces of these systems. Mold problems occur in HVAC systems when accumulated dust and debris (nutrients) become wet and stay wet for extended periods. High humidity within HVAC systems can provide the necessary moisture, and these problems often occur in the southeast U.S. and other areas with hot, humid air. These problems are seen much less often in the arid western U.S. Internal surfaces of ducts can also become wet when water from leaks penetrates through small cracks or seams. This is sometimes found on rectangular ducts with crimped joints. The main air ducts in Building 807 are heavy round steel with welded seams, and not susceptible to water leakage. The terminal ductwork in the building also appeared to be of sound construction and unlikely to be affected by water leakage. Areas imaged using the video camera system did not show evidence of accumulated dust, leakage, or mold growth. The terminal sections of the Induction system were observed in only two locations; Sandia may wish to perform additional visual inspection of the sub-floor sections of this ducting with a suitable camera system. Overall, it is our judgment that the potential for mold growth in ductwork at Building 807 is low.

8.3.2 Health Effects of Mold

In recent years, there has been considerable media and public interest in the health effects of mold exposure. All manner of health effects have been ascribed to the presence of mold in buildings, ranging from those that are scientifically valid to those that are entirely unsupported by scientific evidence. Much research is underway into the health effects of mold, and our understanding is by no means complete. However, it is necessary to make decisions based upon the best knowledge available at the time, and we have therefore taken considerable effort to research the literature with regard to potential effects of mold exposure on the nervous system. It should be remembered that by “mold exposure” we mean exposure to airborne mold at levels that can occur in building occupancies. There is much literature on ingestion of highly toxic mushrooms and of molds that grow on food; these reports must be carefully separated from knowledge about effects on humans from inhalation of mold spores.

The literature review conducted in Phase I failed to associate fungal exposure through the inhalation route with neuropathy, though articles were found dealing with fungal toxins that are “tremorgenic” meaning that they produce tremors. One article has been subsequently found that describes a case of tremorgenic encephalopathy in a young man exposed to extremely high levels of airborne spores[4]. A copy of this article is included in Appendix D. This individual removed moldy fodder for a silo at a dairy farm along with his brother and father. This work produced high levels of dust, and it was later established that molds present on the fodder included the *Aspergillus* species *fumigatus, niger, flavus*, and *clavatus*, along with *Rhizopus, Mucor, Pnecilomyces, Penicillium*, and *Cephalosporum*. All three individuals felt unwell within hours of completing the job, complaining of malaise, fatigue, and headache. The patient and his father became febrile in the next two days and experience chills, nausea, and vomiting. There were no respiratory symptoms. By 48 hours the father and brother had recovered, but the patient developed progressive somnolence, slowness of thinking, and an incapacitating tremor, which prompted his admission to a hospital. An electroencephalogram showed a generalized dysrhythmia, felt to be consistent with a toxic encephalopathy. Within three days of admission, the trembling and encephalopathy had cleared entirely. He was discharged six days after admission and has remained well since, successfully returning to school.

This is the only article referenced in the ACGIH Bioaerosols text[5] showing tremorgenic response of a human to inhaled mold spores. It is important to note that:

1) the exposure levels were extremely high, well in excess of conditions that would exist in mold infested buildings
2) the effect was reversible, with no permanent nerve or CNS damage
3) toxic species of *Aspergillus (fumigatus, niger, flavus, and clavatus)* were involved.

A recent review of the health effects of *Stachybotrys chartarum (atra)* by Dr. Daniel Sudakin[6] (included in Appendix D) concludes that the health risks from environmental exposure to *Stachybotrys* remain poorly defined. He cites one case report in which a group of individuals occupied a water-damaged home containing *Stachybotrys* growth. These individuals complained of headache, sore throat, diarrhea, fatigue, dermatitis, and depression. On removal from this environment the health effects subsided. Another often cited case is the Cleveland infants that were diagnosed with pulmonary hemorrhage and hemosiderosis, ostensibly due to exposure to *Stachybotrys* spores. This study has subsequently been largely discredited in a thorough review that was published in Morbidity and Mortality Weekly Report[7].

We have found no mention of neurotoxicity associated with *Stachybotrys* in the literature, and, in any case, there was no measurable *Stachybotrys* in Building 807. Further, since *Stachybotrys* is always found on high cellulose materials (e.g., the paper on wall board), it seems unlikely that this mold would be a problem in Building 807.

[4] Gordon, KE, RE Masotti and WR Waddell: Tremorgenic Encephalopathy: A Role of Mycotoxins in the Production of CNS Disease in Human? Can. J. Neurol. Sci. 20:237-239, 1993.

[5] Burge, HA and JA Otten. Chapter 19, Fungi In:. Bioaerosols: Assessment and Control. American Conference of Governmental Industrial Hygienists, Cincinnati, 1999.

[6] Sudakin, DL. Stachybotrys chartarum: Current Knowledge of Its Role in Disease. MedGenMed, February 29, 2000 © Medscape, Inc.

[7] U.S. Department of Health and Human Services, CDC. Update: Pulmonary Hemorrhage/Hemosiderosis Among Infants—Cleveland, Ohio, 1993-1996. Morbidity and Mortality Weekly Report March 10, 2000 / Vol. 49 / No. 9.

Based upon thorough review of current scientific literature, we are aware of no credible evidence that inhalation exposure to mold spores found in buildings is capable of producing irreversible damage to the peripheral or central nervous system. In the case cited above, exposure to extremely high levels of *Aspergillus* spores resulted in temporary effects on the nervous system of one of three persons exposed, but these effects resolved, and no permanent neurological injury occurred.